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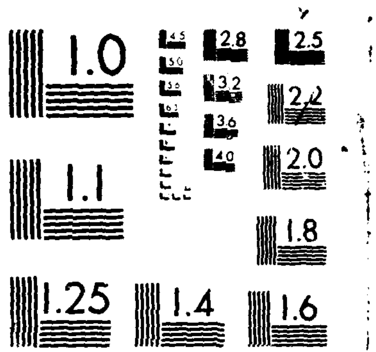

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INVESTIGATION OF THE PHASE EQUILIBRIUM OF ALLOYS OF THE TERNARY SYSTEM Ti-Al-Nb

by

T.T. Nartova, G.G. Sopochkin

FOREIGN TECHNOLOGY DIVISION

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HUMAN TRANSLATION

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В в	*В в*	V, v	Т т	*Т т*	T, t
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К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
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М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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INVESTIGATION OF THE PHASE EQUILIBRIUM OF ALLOYS OF THE TERNARY SYSTEM ~~Ti-Al-Nb~~

Titanium Aluminum Niobium

T. T. Nartova, G. G. Sopochkin

The constitution diagram of the ternary system Ti-Al-Nb has been studied for alloys with a high niobium content [1]. The literature does not contain any data on the investigation of titanium coal of this system with consideration of the formation of the compound Ti^3 in the binary system Ti-Al [2].

We limited our investigation of the constitution diagram of the ternary system ~~Ti-Al~~-Nb to the specific system Ti-Ti^3Al-Nb in order to establish the regions of the α- and β-solid solutions of titanium, the solid solutions based on aluminide Ti^3Al and the phases conjugated with them. The constitution diagram of the systems Ti-Al and Ti-Nb obtained from the data in [2, 3] were used as the basis for constructing the constitution diagram of the ternary system Ti-Ti^3Al-Nb.

The methods of microstructural, thermal and X-ray phase analysis were used in the study. The X-ray pictures were taken in copper emission from powders that had been preliminarily annealed in a vacuum at 600° for 30 min. Iodic titanium, aluminum brand AV-000 and fillet niobium were used as the source materials. The alloys were remelted five times in an electric arc furnace with a nonconsumable tungsten electrode in an argon atmosphere, and then by crucibleless melting in the suspended state. The constancy of the chemical composition of the alloys was monitored by their weight after smelting in an electric arc furnace. The differences between the weight of the charge and that of the ingot did not exceed 0.5%. In order to bring them into equilibrium, the cast alloys underwent the following heat treatment: homogenization at 1200° for 50 hours with subsequent water hardening and stepped annealing at 900° for 100 hours, at 800° for 200 hours, at 700° for 300 hours and at 600° for 500 hours, after which they were cooled to room temperature in a furnace.

The phase equilibrium of the alloys in the system $Ti-Ti^3Al-Nb$ was studied on three radial sections obtained from compound Ti^3Al on the Ti-Nb side with a Ti:Nb ratio of 3:1 (I), 1:1 (II) and 1:3 (III). Some alloys from sections parallel to the Ti-Nb side with a constant aluminum content of 2, 5 and 8% were also investigated. The sections and compositions of the investigated alloys are given in Fig. 1a. The isothermic cross sections of the system $Ti-Ti^3Al-Nb$ at 600, 800, 1000 and 1200° (Fig. 1) and three polythermic cross sections (Fig. 2) were constructed based on the experimental data.

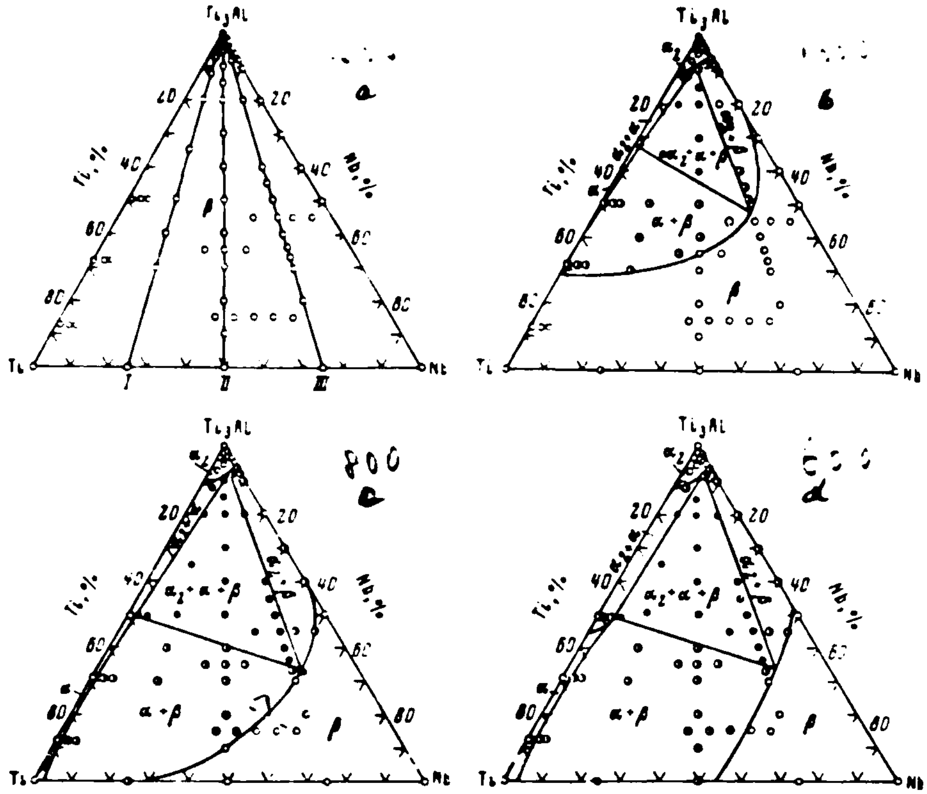

Fig. 1. Composition of investigated alloys (a) and isothermic cross sections of system Ti-$Ti^{3}Al$-Nb (a-d). T, °C: a -1200, b - 1000, c - 800, d - 600.

Earlier we studied the phase equilibrium and properties of alloys of this system along the cross section made from compound $Ti^{3}Al$ on pure niobium [4]. The chemical reaction of the alloys of the $Ti^{3}Al$-Nb cross section is similar to the reaction of titanium and niobium in the binary system Ti-Nb and is characterized by the presence of a continuous series of solid solutions of β-titanium with aluminum and niobium at high temperatures and the limited solubility of niobium in compound $Ti^{3}Al$. Alloying compound $Ti^{3}Al$ with niobium causes a considerable reduction in the phase transition temperature in the solid solution and increases the length of the β-solid solution range. The alloys from this section, containing up to 40% Nb, undergo phase

transformations in the solid state that are similar to the transformations in binary system Ti-Nb. Alloys with a higher niobium content do not have such transformations. The data from the microstructural and X-ray structural analyses indicated that the solubility of niobium in compound Ti^3Al is ~6-5% at 600° and varies little with temperature. We see an increase in the solidus and liquidus temperatures beginning with a 60% total niobium and titanium content on the polythermic section passing through the radial cross section at a titanium-to-niobium ratio of 1:3 (Fig. 2a). The decomposition temperature of the β-solid solution monotonically drops from 1145° for pure Ti^3Al to ~800° at a niobium and titanium concentration of 70%. Compared to the Ti^3Al-Nb section, two new regions appear on the section with a Ti:Nb ratio of 1:3: a two-phase region $\alpha + \beta$ and a three-phase region $\alpha + \alpha_2 + \beta$. The region with a stable ternary β-solid solution of titanium with aluminum and niobium corresponds to 70-100% Σ (Ti, Nb).

Figure 2b shows the radial section of the system Ti-Ti^3Al-Nb at a titanium-to-niobium ratio of 1:1. In this case, the solidus and liquidus temperatures smoothly increase from 1600 and 1620° for compound Ti^3Al to 1740 and 1790° for the alloy containing 50% Ti and 50% Nb.

All the alloys in this section are also crystallized in the form of a continuous series of ternary β-solid solutions. As the total titanium and niobium contents increase, the phase transition temperature in the solid state of the alloys in this section decreases

from 1145 to 650° for the alloy with 50% Ti and 50% Nb. The region of the metallide α_2-solid solution is extended from 0 to ~8% Σ Ti, Nb. The region of the β-ternary solid solution is narrowed considerably compared to the preceding section because of the growth of the two-phase region α + β.

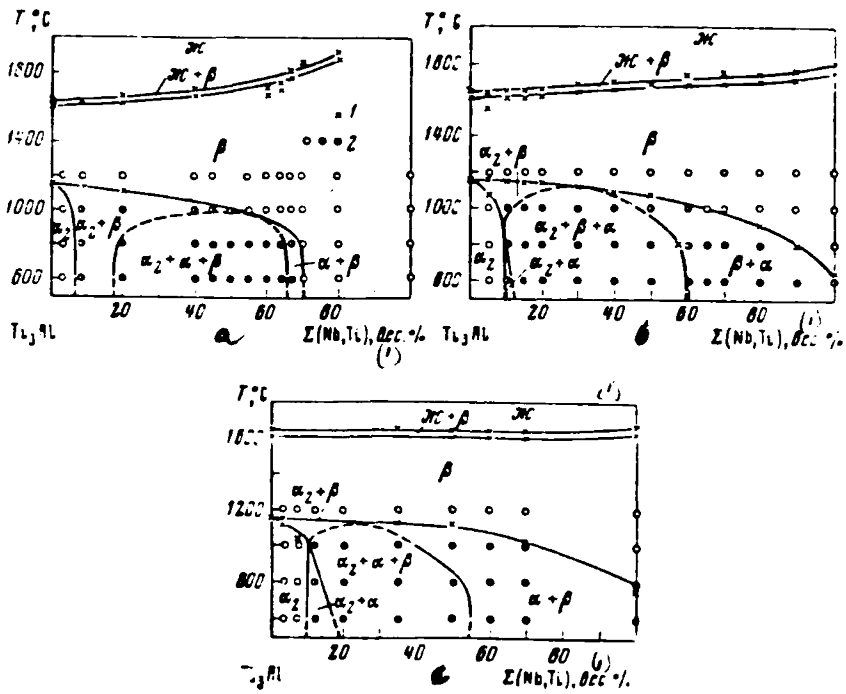

Fig. 2. Polythermic sections of system Ti-Ti^3Al-Nb at titanium-to-niobium ratio of 1:3 (a), 1:1 (b) and 3:1 (c). 1 - data from differential thermal analysis; 2 - data from microstructural analysis.
KEY: (1) % by weight.

The polythermic section with a Ti:Nb ratio of 3:1 (Fig. 2c) is analogous to the section with a Ti:Nb ratio of 1:1.

When comparing the polythermic sections under investigation, we can point out that the nature of the phase interaction in the alloys of the radial sections at a Ti:Nb ratio of 1:3 and Ti^3Al-Nb is determined

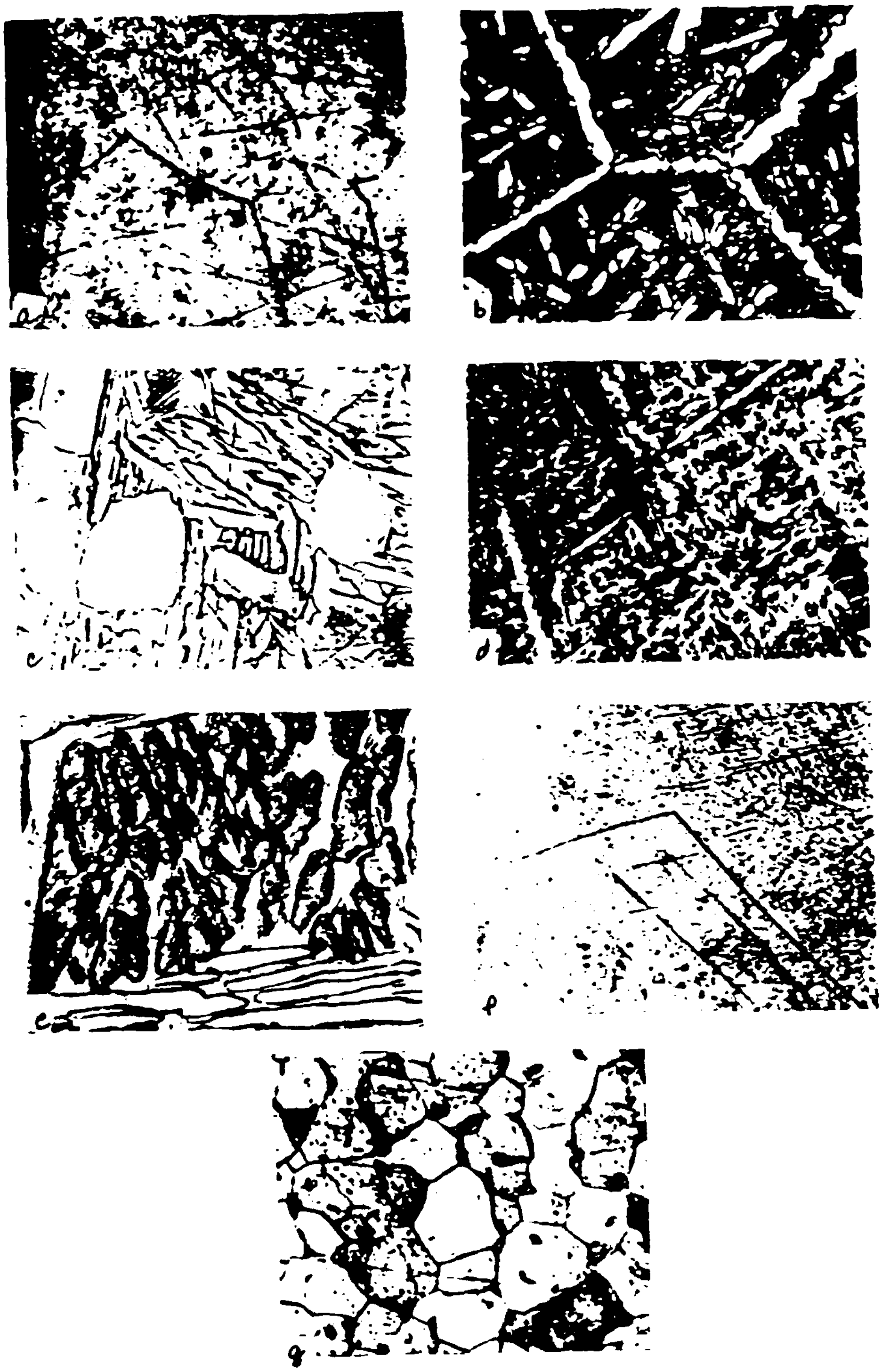

Fig. 3. Microstructure of alloys (see table) of system Ti-Ti^{3}Al-Nb in annealed and hardened states, x200. Number of alloy; T, ^{o}C: a - 1; 600, b - 6; 600, c - 12; 800, d - 16; 800, e - 9; 1000, f - 4; 1000, g - 23; 1000.

to a great extent by the constitution diagram of the binary system Ti-Nb, while in the alloys of the sections with a Ti:Nb ratio of 1:1 and 1:3 - by the nature of the interaction in the binary system Ti-Al.

The isothermic cross sections of the system in question at 1200, 1000, 800 and 600°, given in Fig. 1, were constructed from the data on the polythermic sections and based on the results of the X-ray phase and microstructural analyses of the alloys. The results of the X-ray phase analysis of the alloys in the system $Ti-Ti^3Al-Nb$ hardened at 800° are given in the table. The typical microstructures of the alloys from different phase regions are given in Fig. 3.

As Fig. 1a shows, at 1200° all the investigated alloys constitute a continuous series of ternary β-solid solutions. The region of the ternary β-solid solution occupies most of the concentration triangle in the isotherm of 1000° (Fig. 1b). The solid solution based on compound Ti^3Al occupies a small area at the tip of Ti^3Al. The solid solution based on α-titanium passes through a narrow strip along the side $Ti-Ti^3Al$. There are three two-phase regions - $\alpha + \alpha_2, \alpha_2 + \beta$, $\alpha + \beta$ - and one three-phase region - $\alpha + \alpha_2 + \beta$ corresponding to the three single-phase regions in the system $Ti-Ti^3Al-Nb$.

The same phases were detected at 800° (Fig. 1c) as on the 1000° isotherm. When comparing the isothermic sections at 800 and 1000° it is obvious that the region of the ternary β-solid solution decreased considerably. The region of α-solid solutions widened somewhat and

the length of the regions $\alpha + \beta$ and $\alpha + \alpha_2 + \beta$ increased considerably on the isotherm.

Table. Phases in alloys of system Ti-Ti^3Al-Nb detected at 800°C.

(1) Номер сплава	(2) Химический состав, вес %			(3) Фаза
	Ti_3Al	Ti	Nb	
1	—	50	50	β
2	10	45	45	β
3	20	40	40	$\alpha + \beta$
4	30	35	35	$\alpha + \beta$
5	40	30	30	$\alpha + \beta$
6	50	25	25	$\alpha + \alpha_2 + \beta$
7	60	20	20	$\alpha + \alpha_2 + \beta$
8	70	15	15	$\alpha + \alpha_2 + \beta$
9	80	10	10	$\alpha + \alpha_2 + \beta$
10	85	7,5	7,5	$\alpha + \alpha_2 + \beta$
11	90	5	5	$\alpha + \alpha_2 + \beta$
12	95	2,5	2,5	α_2
13	—	75	25	$\alpha + \beta$
14	30	52,5	17,5	$\alpha + \beta$
15	40	45	15	$\alpha + \beta$
16	65	26,25	8,75	$\alpha + \alpha_2 + \beta$
17	20	20	60	β
18	30	17,5	52,5	β
19	36	16	48	$\alpha + \alpha_2 + \beta$
20	40	15	45	$\alpha + \alpha_2 + \beta$
21	60	10	30	$\alpha + \alpha_2 + \beta$
22	80	5	15	$\alpha + \alpha_2 + \beta$
23	92	2	6	$\alpha_2 + \beta$

KEY: (1) Alloy number. (2) Chemical composition, % by weight. (3) Phase.

At 600° (Fig. 1d) there is a further decrease in the region of the existence of the ternary β-solid solution and an increase in the region of solid solutions based on α-titanium. The two-phase regions $\alpha + \alpha_2$, $\alpha_2 + \beta$, $\alpha + \beta$ and the three-phase region $\alpha + \alpha_2 + \beta$ are greatly expanded at this temperature compared to the 1000° isotherm.

The regions of stable α- and β-ternary solid solutions that occur during joint alloying of titanium with aluminum and niobium were determined on the results of the investigation of the phase equilibrium of the alloys in the system $Ti-Ti^3Al-Nb$, and the maximum concentrations of niobium when it is alloyed with the compound Ti^3Al were established, being equal to 5-6% Nb.

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